

PRESENTER: So my goal with this class is that there's a lot of really amazing classes out there about how to use SSA if you're a civil engineer and you want to drain a highway or a parking lot through a system of underground pipes to a detention pond as rapidly as you can. And I saw this as kind of a resource, maybe for some people outside the profession that also deal with a lot of drainage issues, such as landscape architects and urban planners. And I was hoping that this would be a tool to empower you guys. To empower non-civil engineers.

So if you're a landscape architect and you want to know your craft more deeply, this is the class for you. If you've ever been on a project with a civil engineer, and he trashed your drainage design, and you wanted to push back, this is the class for you. Using the SWMM mode of SSA is an incredibly powerful and empowering tool that will allow you to conceptually validate your own civil H&H, hydrology and hydraulics.

So I kind of conceived this as a class for outsiders that are trying to get in. And as such, maybe a few people will be bored. I'm just going to really build from the ground up, starting with the theory of hydrology, some basics of GIS, anything that you might not be familiar with to get you there. I thought of this class as being more of a high level discussion. If you look on the website, I've written, I think, it's up to 65 pages now that's incredibly detailed. It's got step by step of all of the stuff. So if we run out of time and there's something that we miss in the lecture, don't worry. It's very well documented in almost excruciating detail, like every pick and click you need to do to recreate this type of analysis.

This is my first time to teach at AU, and they had a mentorship program. My mentor said that this was something that people were really interested in. They wanted to know about the speaker and their qualifications. So, right off, I am not a civil engineer. I graduated with a degree in landscape architecture. And it's not very well known in the industry, but landscape architects are legally allowed to design and stamp drainage plants. Usually nobody takes advantage of this professional capacity, though. Hopefully with this kind of simulation software a lot of that will be changing.

As you can see, I've got all kinds of certifications from Autodesk. I graduated from NC State University. It's a relatively prestigious design program. Then I joined the Peace Corps. Then I stationed in Central Asia, I came back, I did a two year internship in America. And then I really

spent the rest of my career working in China for multinational design engineering companies, like AECOM and Parsons Brinckerhoff. And while I was over there, I was really able to take advantage of the very fluid professional boundaries that they have in China. And I moved from the landscape architecture department to the urban planning department to the civil engineering departments and worked as an assistant to the civil engineer.

So I've definitely been trained and I have some apprenticeship experience working under civil engineers. I self-taught hydrology really intensely. And I was able to know it well enough that I actually co-taught a class at Tongji University on civil engineering hydrology for non-civil engineers. And it might not mean a lot here in the United States, but Tongji is like the MIT of China.

Currently-- I moved back to America last year-- and I work for the Hyphae Design Laboratory in Oakland. We get a lot of questions about this. Hyphae is the anatomical structure of a fungus that grows up to several square miles underground connecting the root systems of trees. And it actively transfers nutrients between the trees and the soil. And the founder of our company conceived this as his motif because he wanted us to work in an incredibly interdisciplinary environment that filled in a lot of the gaps between the traditional information silos within the AEC industry. And the laboratory aspect is not just marketing or branding. We really do a lot of research in-house. We have an ecologist and a biochemist on staff. And I don't think since I've been there any two projects have been the same. We do really unique stuff and there's always a research component to every project that we work on.

OK, so that's my plug for my company. One of the first projects that I worked on when I was at Hyphae Design is the Esalen Institute in Big Sur, California. And this will also be the case study that we'll be looking at today when we're looking at the SWMM model. So if you're not familiar with it, the Esalen Institute is the epicenter of the New Age movement. This is where it all started. And it's appropriately enough located in this very picturesque region of the world, probably one of the most beautiful regions of the world, the central coastline of California.

Is this laser pointer going to work? I guess the laser pointer does not work.

What you're seeing in the picture on the left, that's the mountains, that's pretty much what our site looks like. They just dive straight down into the ocean. And between the mountains and the ocean is this very narrow strip of Highway 1. And this is the naked hippie hot tubs here, that's kind of nestled into the mountainside. And what our clients wanted to do is expand their

facilities here, back into the mountains. And as you can see from the terrain, it's very steep.

So what they wanted to do was a series of these earth-sheltered buildings with these green terraces between. And on the green terraces is where they were going to locate the BNPs to treat the stormwater. And it was all going to flow through the system. And there's a culvert right here that goes under the road and dumps into the Pacific Ocean. And because it's all these new age hippies at Esalen, they were very, very concerned with the ecological footprint that they were going to create by building this. So we're willing to invest the time and money in having us do a very detailed SWMM analysis to see what was going to happen with the water quality and quantity on the site. So that's some background on the case study.

OK, very quick overview of hydrology. Storm water management is as much an art as a science, requiring judgment in the use of available data and calculations. And that was certainly my experience of learning hydrology as an outsider. It almost felt more like a black art sometimes than an engineering profession. And the most difficult part wasn't necessarily making the calculations, it was making the right assumptions before you begin the calculations. So that way, the results aren't garbage. I've heard that from a lot of people that studied hydrology too. There's an experience component to it that you just can't get without trial and error.

OK, so in brief, hydrology is the study of the space, time, and mass, of water as it moves through the landscape. As land planning professionals, we're all very familiar with space and mass. Doing things like grading or doing things like the volumetric calculations for BMP. Where it gets really complicated and where we need custom software, like SWMM in SSA, is when we start looking at the aspect of time and when we apply the time base to the calculations. And this is basically, in short, this is what's going on under the hood the whole time.

So you have-- in this example-- you have a rainfall that's landing on the roof. And it's sliding down the roof. Depending on the angle of the roof, faster or slower. And then it goes through the gutter, concentrates in the gutter, and then it concentrates again in the pipe. So the rainfall has a certain rate coming in. It gets transformed by the surface of the roof and the gutter and has a very different rate going out again.

And so that process input, transform, output. Input, transform, output. That's what's going on and on-- that's what's happening over and over again in every element within the SSA SWMM model. And what that produces, as the output you're seeing on the right, is what's called a

hydrograph. It's a mass to time graph. And every element in SSA has its own unique hydrograph. The rainfall depth is in blue on top and the runoff output is the red line. OK, and this-- maybe this can be done in a spreadsheet through convolution if you really wanted to.

People used to calculate this stuff by hand. But where it gets very complicated, and this is where you absolutely need the software, is what's called routing. Because every element in the system, every pond, every channel, every rain barrel, every infiltration trench, roof, subbasin. They're all reacting to rainfall differently in different times in different ways. They all have their own unique hydrographs. And they feed into each other. They combine. They diverge. They can even form feedback loops. And, depending on the scale of your project, it gets so complex it's virtually impossible for a human being to keep track of it all. And that's where the software comes in. It manages not only the calculation, but the routing as well.

There are two routing options in SWMM. Kinematic wave and hydrodynamic. The kinematic wave is an approximation of the Saint-Venant equation, which is a partial differential equation that's used to calculate the way water is moving through the system. And the hydrodynamic is the full Saint-Venant equation. So as you're setting up the analysis options within SSA and you're using SWMM, make sure you always use hydrodynamic mode or you're just not getting your money's worth. You're getting an approximation instead of an exact result.

OK so why swim? This was-- when I was learning hydrology-- this was one of the first roadblocks that I hit. One of the first real challenges or difficulties. There's not just one system to deal with routing. There's many, many different routing methods. And in addition to all those different routing methods, there's many different softwares that implement those many different routing methods differently. So if you only have time to invest in one and you're under the gun at work, how do you get started and which one do you choose?

So let me just focus everyone in SWMM. SWMM is the answer. If you're ever in doubt, choose SWMM. The reason why is because a lot of the methods predate computers. And they were designed to be easy to calculate by hand and not necessarily because they were exact. The second reason is that of all the analysis options in SSA, SWMM is the only one that uses hydrodynamic. So you're really not going to get your money's worth unless you use SWMM. And finally because SWMM is the only analysis mode that has the option to analyze water quality as well as quantity. So when you use SWMM, you can introduce pollutants into the system. You can introduce TSS into the system and track it throughout, which is incredibly useful and was used in this project to meet legal compliance requirements. You're able to

submit a SWMM model to the county, for example.

Just as long as we're talking about SWMM, there's an interesting side note. It was developed in the 1970s and it was purpose built toward managing storm water in urban environments, which is where most of the development is happening now. So in a lot of ways it's better suited than something like TR-55 to deal with the typical urban projects.

Open channels. As I mentioned earlier, a lot of the classes out there, which are amazing and excellent, they're kind of targeted toward a civil engineering audience. And it's about how to drain a highway or a parking lot through drains into a detention pond. Whereas if you're working the typical urban planning or landscape architectural project, it's very soft. There's a lot of green infrastructure, a lot of very delicate design. And mostly you're using a lot of open channels and open ponds. And there has not really been a great resource on that yet so I hope to fill in the gap.

This class actually grew-- the seed that this class grew out of was a long post that I wrote on the Autodesk forums about how to create open channels using simple 3D and SWMM and analyze them in SSA really fast and efficiently. If you want to understand open channels in SSA, you will need to understand the SSA node object. That is the key to it.

So a really good way to think about the nodes in SSA is just imagine these idealized cylinders and they have four levels. The invert at the bottom. The water surface elevation, initial water surface elevation, which is very unhelpfully labeled WSEL in your dialogues in SSA, something called the surcharge, and then the rim is at the top. Anything above the rim flows out of the node and it goes into-- you can imagine this is a second conceptual cylinder sitting on top of the first one. All of the flooded, overflow water shoots up into that cylinder and it just hangs out there until the hydraulic grade drops enough and then it drains back into the system again. And that upper cylinder that stores the flood water, again in the very unhelpful units of acre-inches, has another quality called the ponded area, which is not a level so much as an area. And we'll look at that more in depth when we get to the storage nodes part of the lecture.

Just jumping back really quick. The surcharge, in case you were curious, it's the air gap between the water surface and a sealed lid in a sealed system. And that's why it doesn't really apply to open channels because you're never going to have that condition. Basically if it was sealed, when you go over the surcharge the system becomes pressurized and it falls under a different set of mathematics. The other kind of gotcha that I found out when I was modeling

this stuff is the way depth is dealt with. Depth is measured upward in positive units from the invert to the rim.

OK so hold all that in mind. The way that SSA sees open channels-- in the real world you have this very lovely delicate channel that you designed on your site with all kinds of flourishes, and it varies in width and depth as you go along. And if you imagine slicing typical sections along this, each one of those typical sections would translate into a junction, an SSA node object that has its own rim and invert depending on the depth. And then stretched between those are uniform channels.

So you can see here in the real world it's very narrow and then it kind of flares out and gets narrow again. And so the way you would translate that into your SSA model is kind of average this out. Have a narrow shallow channel going into a junction. And then here, kind of average this out and have a wider, deeper channel going to a deeper junction. And then another narrow shallow channel going out to another junction. So you can approximate the variety and complexity of open channels in a single line diagram, in Civil 3D, using poly lines for the channel center line and blocks to represent the SSA junctions. Then you wrap the whole thing up into a shape file and shoot it into SSA.

All right and let's look at that little bit of live demo. This is the site of Esalen. These are all the buildings here. These are the different terraces that we've roughly graded into the hillside. This is a service road that goes around the edge. There's a massive mountain on this side and it's going to flow down and get intercepted in this swale. So this is the high point of the swale and it drains all the way here into this culvert and passes underneath the road.

So we're going to lay out a demo open channel between the high point and the inlet. This is a typical, classic Civil 3D pipe object. By the way, I gave you guys this block in the materials that you can download for the class. This is an SSA-- this is a node block from AutoCAD that will be turned into an SSA junction object. OK so if you look within it, down here in the custom properties we have all the different levels of the section that I was talking about before. The rim, the depth, the invert, the initial water surface, the surcharge, and the ponded area. And with these, all you really need to think about is how deep you want your open channel to be. So in this case it's going to be one foot.

So I'm going to put the end point here. This thing is so slow. This part's really important. You see where the node is on the structure-- on the Civil 3D pipe structure. You have to have the

center point of your block exactly on top of that thing. There's not a lot of fuzzy tolerance in SSA when you import this stuff. You've got to really line things up right on top of each other.

All right so we've got both of our vertical controls in through these blocks. Now we're going to put in our horizontal control. And here all you really need is a polyline. All right so this polyline is representing the horizontal part of the channel. The next step is to send these blocks to the surface. So we go to modify, surface, move blocks to surface, and then it's saying to select the surface. That's the hydrology reference. And then select the block.

This part, I documented it. It's a little bit annoying, but you have to regenerate it twice. So what happens is Civil 3D shoots all these blocks up to the surface, it hits the surface, and that's the number on top. That's the rim. And then remember we entered in a depth of one foot. So it subtracts out a foot and calculates the inverts. And the reason you have to re-gen twice is the first time it calculates the rim and then there's a formula inside the block-- that's why you have to re-gen again-- to run the formula inside the block to get the invert. So, for example, on this one let's say that we want it to be two feet deep instead of one foot. Just change this to a two and then run it again. So you can control your vertical through the blocks and your horizontal through these polylines.

So if we jump ahead to this file, where I've magically completed-- diagrammed out all of the flow paths-- all of the open channels in the system. If you look at these poly lines it has attach properties from map 3D. The Manning's n value and the depth of the channel are inputs that you're going to want in SSA. So the way that you do that-- I think the command is called map-- so you use the command ADE attach, and you can create a data table that will attach extended data to the AutoCAD objects. So now we've put in a Manning's n value and a depth to that polyline. So let's say that we wanted it to be lined with concrete instead. We just turn the Manning's down to 11. So that way you can manually edit it object by object if you need to or do all of the objects at once, depending on how you want to attach the tables.

OK so once you get everything diagrammed out, as I mentioned, the next step is to send it all to a shapefile that you can import into SSA. And the way you do that is with the command map export. It's going to prompt you for a location. Let's put it on the desktop. And make sure that you use a shapefile. OK and then you can only import one object type at a time. So you have to create two separate shapefiles, one for the points and one for the lines. So we'll do points first. Here I'm just going to select one, but you want to do the whole set. So you select all of your objects and then go to the data tab, and then select the attributes. And what you want is

the length property. And then go down here to the object data. This was the table that we created. And you want the n value and the depth. And then OK. This part's really important. Make sure that you have a coordinate system in your drawings settings in your Civil 3D file before you export to make sure everything is going to line up in SSA correctly. I'm not going to crash my computer by exporting it, but then you would export it.

And then moving over to the SSA side. Oh, sorry. I totally forgot I got to look at-- I apologize. I kind of flew through that. To get the blocks in it's actually a lot simpler than the lines. You select the data attributes. All you have to do is click on the block attribute and it's going to have everything that you need. So that one's just one click. OK so what that's going to do is generate two shapefiles. Points and lines. Horizontal and vertical control. And what's really neat about SSA is that you can merge data from multiple sources. So you can actually merge the pipe system, the Civil 3D pipe system, and these custom open channels that you're creating together into a single network. So when you're doing that, the order's very important. Always begin with the pipes.

OK so these are all of the culverts and some of the drainage pipes in the design. The next step is you want to convert all of the outfalls into junctions. Except for the ones that are the actual outfalls of your system. Then the next step is go to import and go to the GIS wizard. By the way, if you guys have ever looked at this graphic on the side and wondered where is this, it's actually right next to my house in San Francisco. It's the Twin Peaks area. OK so for pipes this is where you choose the shapefile that you created from the open channel center lines. Make sure that append is on. I found that this is best at one foot. If you make it lower than one foot, like a fractional number, the whole thing will crash and the import won't work. So the pipe diameter then becomes the depth.

And the Manning's roughness, you want to put in the n value that you created. The length should match up automatically. And then when you import the junctions everything should come in correctly. OK, so now you've just merged an open channel system together with a pipe system to form a complete network of both open and closed channels.

So if you look here, this part of SSA is really annoying. You can't have different-- there's no way to specify in Civil 3D whether you want this to be a parabolic swale, or a trapezoidal channel, or your own custom section. You get one import option that everything is supposed to be-- you have to go back manually and change it. You have to step through every single one and change it. And the same for the side slopes. There's no way, yet, to edit this as a table all

at once. So depending on the size of your project that can be really annoying.

OK so that's how to merge open channels and pipe networks together. This somehow lost track of where I was, which is also annoying.

Subbasins are a beast of data to deal with. That was one of the things that really shocked me about building these models. I thought I would be in the hydrology model or doing all this stuff in complexity, but it actually turned out maybe 80% of the work was just prepping the data to put into the model. And then you hit run and in a couple of seconds it's all over. And subbasins are the worst, the absolute worst, for compositing stuff together.

OK so the way-- if you think back to the open channels example-- the way that SWMM in SSA sees a subbasin is that all that lovely complexity of the landscape, it gets abstracted and turned into a rectangle that has a length, a width, an area, and is perfectly bisected by a flow path down the center. And the problem is if your design is not a rectangle that's perfectly bisected by a flow path down the center, how do you communicate that to SSA? And that's where the very unique SWMM method of finding time of concentration comes into play. This is really buried in the documentation of the SSA manual. But essentially the way they do time of concentration in SWMM is that, that center flow path, that's assumed to be the time of concentration line. And if the areas on either side are unequal you have to calculate a skew factor. And that's multiplied against the length and the area to find what's called the equivalent width. And based on that equivalent width factor, that's how they get time of concentration.

So in some ways it's easier and in some ways it's more complex maybe than what we deal with in TR-55 and rational method. You probably already surmise, just by looking at the diagram, this is a very GIS intensive operation to extract these skew factors from the data. So these are the physical properties of the subbasin. Length, area, skew factor, equivalent width, and slope. Those are the major factors that push the hydrograph one way or another on simulation. But, in addition to those, the hydrograph can kind of be tweaked.

I call them the minor factors. They're the material factors of the subbasin. So as you can see in this example image, water moving across a hard, smooth, impervious surface moves a lot faster with more volume than water that flows across a very soft, pervious surface. And the way, again, the way that you get SSA to see the materials that you're using in your design, you have a loss factor. That's a combination of interception by the plants and infiltration. And that uses the classic SCS curve number. And the velocity is controlled by Manning's n factor to

account for the friction.

In addition-- this is something that's kind of unique to SWMM-- you have to enter in the fraction of the surface that is paved. And the reason why is because SWMM has built into it factors that describe how many pits there are in the microtopography, which is different, obviously, for a parking lot versus a grassy field. And those pits translate into puddle storage that's later evaporated during a rainstorm, which is also a type of loss. Again, as you can surmise by looking at this, this is another very GIS intensive operation.

Which brings me to GIS. It would be really nice if our clients handed us all of the data that we need, not only for the site, but also for the watershed that our site occupies. Usually that's not the case and when it's not the case you're going to have to go online and search down some GIS data stores. The county level was always best and if you can't find that the universal backup is to go here, to the National Resource Conservation Service website.

And it's kind of a one-stop shop for everything. It has land covers. It has soils. It has topography in case you're missing terrain within your watershed. It has all of the data that you're going to need, maybe not to make the calculation as well as you would like to make it, but it has enough to get a meaningful result.

If you've ever worked at GIS before you know that GIS generates a tsunami of data as it runs through various geoprocessing operations. And there's no database to manage like we have with Esri. So you have to create your own document object model, which is something that maybe you've never heard it called that before, but you're very familiar with it.

If you look in SSA, here on the side, this is an example of a document object model. And also in Civil 3D, in the tool space, another example of a document object model. And what you can see with both of these is that stuff that is the same accumulates under that branch and node on the tree. And that's all it is. So when we look at the document object model for our GIS it's exactly the same as tool space. There's different types of GIS outputs that we're going to get and they accumulate within their node. And it may seem a little bit fussy, but as the design goes through a lot of iterations and changes it's going to get harder and harder to keep track of this flood of GIS files that are going to get generated.

Before I jump into the live demo for some subbasins, this isn't in the handout. This is kind of the overview of what we're going to be doing step-by-step. So you have the hydrology file. And that's got stuff like the time of concentration line and the subbasin in it. You've got a material

file. And you've got a separate GIS work space. Of course you're welcome to set it up your own way. I just found that when I keep the GIS stuff separate from the Civil 3D stuff, because Maps 3D is so much less stable than Civil 3D, when it crashes and you get a fatal error and you can't recover the drawing it won't contaminate the rest of your data.

So, in brief, starting with these AutoCAD files, you create using the map export function. You export out the geometry as different SDF files. And by the way this is not optional. You have to export them in SDF. And the reason why is because SDF is Autodesk's custom GIS file format. So out of all the different GIS files you can load into Map 3D this is by far the most stable one and is going to keep your system from crashing when you do overlay analysis. And then you guys can kind of redo this on your own, but you have to go through the series of different GIS steps like querying and intersection overlay.

You have to do some table calculations and you just kind of smash the stuff together until you've extracted every possible geometric property you can out of it. And then at that point you export out the tables of everything and you finish it in spreadsheet. And then you do what's called a table join in GIS and bring it back in-- connected back up with the basins. And then you shoot that file out as a shapefile into SSA and merge it into your network.

This is just really quick because I think class is about to end actually. It's 5:45. I've got about 15 minutes.

So here, this purple area, this is the extent of the grading work, the extensive site that's being impacted by the design. And what I found the painful way is that it's really complicated to figure out what exactly is your study area. So the workflow that I came up with is you look at what the impacted area is and then you find out what is the smallest possible subbasin I can draw around that that goes to my outfall point and contains this area. So, in short, you work from the outside in and it saves you a lot of trouble and confusion when you're diagramming out these subbasins.

All right so here, that's the big, fat, red outline of my master subbasin. So starting with that, you can use the water drop tool and a lot of different analysis tools in Civil 3D. I'll just jump forward to create this kind of a diagram just using polyline objects. The really important thing here, because this is going to become GIS geometry, these red outlines of the subbasins have to be really clean. They can't be little overhangs and gaps or it's going to fail when you try to import it. So just do your best and use the map clean function to make sure this is as clean as

possible.

And the other kind of gotcha-- the reason why this line type has the arrows on it is that when you draw these things it has to flow from the highest point to the lowest point because we're going to turn these into Civil 3D feature lines and elevate them to the surface. And then we're going to pull out the high and low points and calculate the slope from that. So if you've got it going in the wrong direction you're going to end up with negative slopes when you try to import it.

I found that the fastest way to transfer this stuff is with the Civil 3D parcel object. I gave you all of these styles and the stuff you can download from the class. So what's really great about this one is that this fuzz of dots around the edge-- say that this isn't closed all the way-- these dots are going to flood from one end to the other. And anything that you've misdrawn is going to jump out at you really fast. So it's a great way to check for errors. So this is the drainage basin network and the time of concentration lines.

So a couple of quick things about this. This is just for the purpose of exporting it to GIS. The way that these labels are set up is really important. The way Civil 3D exports, it's not possible to get the parcel number. You have to clip the parcel number out of the parcel name. So the way that you generate the parcel name is really important when you do the calculation later in GIS to extract the number data from it. So these are all stored in their own site called subbasins.

And then there's another site for the time of concentration feature lines. And as we discussed before, in addition to the actual area of each subbasin, we need the area on either side of this line. So we have to create another site that has the subbasin halves that are shown here in blue. And we have to get all of those areas in addition. And so you do that, as you can imagine, by creating another site called subbasin half that has another parcel topology in it. And once you've got all that, you go here to output and export Civil objects to SDF. And then you click through the screens and make sure you put it within your document object model.

And once you have those then you are finished with the Civil 3D side of things. You switch over into the Map 3D functions within Civil 3D. And if you're not familiar with Map 3D basically in the command line just type map W space and it's going to pull up this thing called the task pane. And pretty much every tool or function you're going to need you can find in this. So I'm not going to actually do the GIS operations because it's going to crash my system for sure, but

I set everything up in advance so I can click through and show you what you would do.

So this is the raw import here. This was the SDF file that we just exported. And if you notice, it's got parcels from both sites mixed together. So here is subbasin one for example. And then here is the subbasin halves. It's all mixed together. And the way you separate that in GIS is with something called a query. So here we've queried out just the subbasins. It's this button here that looks like a filter because it's a filter. And this is documented in the help files. It's a little bit annoying and complex, but it's similar to SQL.

So here what we're saying is we want only parcels whose names contain the words "hid," and that will pull out just the subbasin. And then you do the same thing here with the subbasin halves. And then once you've queried it you export the layer to an SDF. And when you do that it makes the query permanent. It drops out the stuff that is not being queried. And then you load those files back in. And once you have the basins back in you have to create what's called a calculate in GIS.

So this is the calculation. This is why I was emphasizing the parcel name before. What this calculation does is it clips off the last two numbers of the parcel name, which is the parcel number, and then turns it from a string of text into an integer. So these IDs are really important because this is what's going to unite all of the data back together in the spreadsheet. After that you would take your land cover and your soils. And then do what's called map GIS overlay. So for the source we're going to-- this is our subbasins with the hydrologic ID number and this the land cover here. And then you do an intersect. And what it will export-- it will assign an ID to each land cover type. So now each land cover and each soil gets tagged by an HID, and then just following the flow chart and the instructions, you just keep smashing it together and together and together. And then at the very end, when you've generated all of your data, as much as you can from the GIS, you select all and then you export it out to a CSV file here in the tables node.

OK and then you take all of those tables-- this template is in the class materials-- and you copy and paste each of those CSVs into this table. And I've built these spreadsheet functions in. And what it does is it searches through the entire array of data and it finds, just by the land cover type and by the soil, it will create a weighted average of what the curve number should be by each subbasin. And when this table is finished you jump back into GIS and reunite it and you can create a shapefile. And then within SSA, you jump back to the GIS import and go directly to subbasins. And choose this one. And match these up. The ID, the area, the slope,

the percentage of impervious area, the impervious Manning's number, the pervious Manning's number, the curve number, and the equivalent width. Press finish and then you've got all of your basins with their correct hydrological characteristics loaded into SSA. So area, width, the weighted average of the curve number, et cetera. This part's really annoying. You've got to manually connect these one by one to the correct junction to analyze the system.

So in the last five minutes of class let me just jump forward. This is a little bit experimental. This is meant to be a bioretention cell, also called a flow through planter or a rain garden. And That has properties of surface storage and subsurface storage with a filtration media between. I was on the phone with Autodesk a lot about this. Apparently this is kind of an experimental thing and there's no solid documentation on it yet, which I hope is one of the things this class will fill in. This method that we came up with is actually based on the work of Edward Houston in 2006 from Virginia Tech. He came up with this modeling technique and then validated it in field. So the way to model a complex BMP like a bioretention cell, you actually need two storage nodes. One for the surface pool. One for the underground storage. You need an overflow. And in addition to that, you need what's called a water quality orifice, which is an orifice with a very, very small diameter that is slightly above or at the invert elevation of the biocell pool using a coefficient of 0.65. There's a little bit of reverse logic to this. The way you get the diameter for the water quality orifice is you sit there and run SSA over and over again and keep looking at the drawdown time for the pool. And just keep expanding or contracting this until you get about 30 hours and that should simulate correctly the filter media between the underground storage and the surface pool.

And in the last two minutes of class, this was the other BMP that we wanted to look at. These are gravel-lined infiltration trenches here along the road. There's a little bit of reverse logic to how those work. So the infiltration trenches has an underground storage that fills up with water. It surcharges and floods and then flows through a gutter. But that's functionally equivalent to having a gravel-filled storage that floods up with water and then flows over a weir, where the weir length is equal to the length of the gutter, and then falls into the gutter. You end up with the same result. So that's what we used here in SSA. So this subbasin drains into the underground storage for trench two and then it crests over a one inch weir that has the same length as this gutter filled with-- you can create custom sections in SSA that has a custom channel section with different Manning's depending on the overbank and on the surface. And that's apparently the orthodox way to do an infiltration trench.

So with that we are at time right now. Thanks everyone for coming.

[APPLAUSE]